

Preliminary Report  
Hurricane Earl  
31 August - 3 September 1998

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National Hurricane Center  
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Earl made landfall on the Florida panhandle as a category 1 hurricane on the Saffir/Simpson Hurricane Scale (SSHs), resulting in significant storm surge flooding in the “Big Bend” area of Florida.

a. Synoptic History

Hurricane Earl formed from a strong tropical wave that emerged from the west coast of Africa on 17 August. Persistent convection accompanied the wave as it moved westward across the tropical Atlantic. A weak surface cyclonic circulation was suggested in animation of satellite imagery, as well as in limited aircraft reconnaissance and island reports as the system passed through the Lesser Antilles on 23 August. Tropical cyclone development appears to have been inhibited while the system moved through the Caribbean by unfavorable winds aloft. These unfavorable conditions were a result of the upper-level outflow from large and powerful Hurricane Bonnie located over the southwest North Atlantic and moving toward the North Carolina coast. Nevertheless, the tropical wave continued to be easily tracked in satellite imagery as it moved into the Gulf of Mexico where cloudiness and thunderstorms increased. The post-analysis “best track” in Figure 1 shows that the system became a tropical depression over the southwest Gulf of Mexico midway between Merida and Tampico, Mexico at 1200 UTC 31 August. Best track position, central pressure and maximum one-minute sustained wind speed are listed for every six hours in Table 1.

The tropical depression became Tropical Storm Earl while centered about 500 n mi south-southwest of New Orleans, Louisiana near 1800 UTC 31 August based on aircraft reconnaissance data. The center remained difficult to locate by satellite, and, in fact, multiple centers were reported by aircraft reconnaissance for the next couple of days. Occasionally, a new center would appear to form which made tracking extremely difficult. Although the best track shown in Figure 1 indicates a general motion toward the north and then northeast near 10 knots while Earl was over the

Gulf of Mexico, a certain amount of “smoothing” was necessary to account for the multiple centers and any possible center reformations.

Based on aircraft reconnaissance data, Earl is estimated to have reached hurricane status at 1200 UTC 2 September while centered about 125 n mi south-southeast of New Orleans, Louisiana. The system never exhibited a classical hurricane appearance. Instead, satellite imagery showed the deepest convection confined primarily to the eastern quadrants of the circulation and aircraft reconnaissance data indicated a very asymmetric wind field with the strongest winds located well east and southeast of the center.

After briefly reaching category 2 status on the SSHS, Earl made landfall near Panama City, Florida as a category 1 hurricane near 0600 UTC 3 September. The strongest winds remained well to the east and southeast of the center which resulted in the highest storm surge values in the Big Bend area of Florida, well away from the center. The tropical cyclone weakened to below hurricane strength soon after making landfall, and became extratropical at 1800 UTC 3 September while moving northeastward through Georgia. The deepest convection became well removed from the center by this time and the strongest winds were located over the Atlantic waters off the U.S. southeast coast. The extratropical cyclone moved off the mid Atlantic coast near 1800 UTC 4 September, crossed over Newfoundland on 6 September and was tracked across the North Atlantic until being absorbed by a larger extratropical cyclone (formerly Hurricane Danielle) on 8 September.

#### b. Meteorological Statistics

Figures 2 and 3 show the curves of minimum central sea-level pressure and maximum one-minute surface wind speed, respectively, as a function of time. The observations on which the curves are based are also plotted and consist of aircraft reconnaissance data and Dvorak-technique estimates using satellite imagery, as well as synoptic “fixes” from surface data after landfall.

The operational aircraft reconnaissance flights into Earl were provided by the U.S. Air Force Reserves. The minimum central pressure reported by aircraft was 985 mb at 0045 UTC 3 September. This minimum pressure was measured by dropsonde and was the lowest pressure reported during Earl’s existence. The maximum winds of 104 knots from a flight level of 850 mb (near 5,000 feet) were measured at 1638 UTC 2 September. These peak winds were in a limited area about 80 n mi east of the

center. The Hurricane Hunters never reported an eyewall. Reconnaissance data and land-based radar presentations suggest the hurricane weakened before moving onshore.

Satellite estimates underestimated the intensity of Earl, likely due to the fact that Earl never exhibited a classical tropical cyclone pattern. For example, the maximum winds estimated from the Tropical Analysis and Forecast Branch (TAFB), the tropical branch of the Air Force Weather Agency (AFGWC in figures) and the Synoptic Analysis Branch (SAB) were 55 knots, 55 knots and 45 knots, respectively.

The WSR-88D (Weather Surveillance Radar - 1988 Doppler) at Slidell, Louisiana, Mobile, Alabama, Eglin Air Force Base, Florida and Tallahassee, Florida were helpful in locating the center and areas of strongest winds aloft as the cyclone moved near shore.

As is often the case in landfalling hurricanes, there were no reports from land stations of sustained hurricane force winds in Earl. Table 2 lists selected U.S. surface observations. The NOAA C-MAN station at Cape San Blas (near Apalachicola, Florida) reported 10-minute sustained winds of 48 knots between 0400 and 0500 UTC and gusts to 61 knots at 0436 UTC 3 September. The strongest winds at the time of landfall likely remained over water near the Big Bend area of Florida.

Several wind reports from north Florida were relayed to the NHC through amateur radio volunteers. The highest measured wind gust was 79 knots at an elevation of 33 feet from a Davis wind instrument located in the middle of St. George Island at 29.40N 84.53W at 0102 UTC 3 September. Although these measurements are very much desired to supplement the more official observations, they will not be listed in Table 2 unless their accuracy can be verified.

Storm surge was estimated to be near 8 feet in Franklin, Wakulla, Jefferson and Taylor Counties and approximately 6 to 7 feet in Dixie County. These values tapered off to between 2 to 3 feet in Lee County.

Rainfall totals of three to six inches were common near the path of Earl, although much higher amounts were recorded in a few areas. A storm total of 16.38 inches near Panama City, Florida, was the highest reported.

Several tornadoes were reported in central and north Florida, Georgia and South Carolina.

A rather extensive sampling of the Gulf of Mexico with GPS dropwindsondes by the NOAA jet, centered around 0000 UTC 2 September, showed a mid-level trough extending into the central Gulf which provided the steering currents that moved Earl northeastward into the Florida panhandle.

#### c. Casualty and Damage Statistics

Hurricane Earl was directly responsible for three deaths. Two deaths occurred as a result of a boat being capsized off Panama City. One death occurred as a result of a tornado near St. Helena, South Carolina.

The Property Claim Services Division of the American Insurance Services Group estimates that Earl caused insured property damage of \$ 15 million in Florida, \$ 1 million in Georgia, and \$ 2 million in South Carolina. These estimates do not include storm surge damage. In addition, the National Flood Insurance Program reported \$21.5 million of insured (storm surge related) losses in Florida. A conservative ratio between total damage and insured property damage, compared to past landfalling hurricanes, is two to one. Therefore, the total U.S. damage estimate is \$ 79 million.

#### d. Forecast and Warning Critique

Several forecast difficulties were encountered during the life of Earl. As already stated, the center was very difficult to locate by satellite and aircraft reconnaissance continued to report multiple centers. Various computer models showed more than the usual scatter in track forecasts. For example, the 72 hour model forecasts initiated about a day and a half before landfall predicted that the center would be located anywhere from the northwest Gulf of Mexico (Navy NOGAPS), to northern Arkansas (BAMD), to northern Mississippi (GFDL), to over the Atlantic southeast of Cape Cod (LBAR). In addition, 36 hours before landfall, most computer models incorrectly showed a landfall somewhere in Louisiana. The BAMD, BAMB and the GFDI (interpolated version of the Geophysical Fluid Dynamics Laboratory model) provided the best guidance in terms of the lowest average track forecast errors at 48 hours.

During Earl's life as a tropical storm or hurricane, the average official track forecast errors were 84 n mi at 12 hours (10 cases), 156 n mi at 24 hours (8 cases), 261 n mi at 36 hours (8 cases) and 296 n mi at 48 hours (4 cases). These errors are considerably larger than the previous ten-year averages of the official track errors.

The NHC intensity forecasts showed a negative bias (i.e., intensity was underestimated), but most NHC intensity forecast errors were 15 knots or less prior to landfall. Initial intensity forecasts correctly indicated that Earl would strengthen into a hurricane.

Table 3 lists the various watches and warnings that were issued. Since the NHC forecasts are based, in part, on the computer guidance, hurricane warnings were not issued with as much lead time as the NHC desires. Fortunately, appropriate preparations appear to have been completed anyway.

### **Acknowledgments**

Some of the information in this report was provided by NWS offices in the Southern Region and is greatly appreciated.

Table 1. Best track, Hurricane Earl, 31 August - 3 September, 1998.

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
31/1200	21.6	93.5	1005	30	tropical depression
1800	22.4	93.8	1002	35	tropical storm
01/0000	23.2	93.7	1002	35	“
0600	24.1	93.4	1001	40	“
1200	25.0	93.1	999	45	“
1800	25.8	92.5	998	50	“
02/0000	26.8	91.5	998	50	“
0600	27.6	90.4	996	50	“
1200	28.2	89.0	994	70	hurricane
1800	28.7	87.9	988	85	“
03/0000	29.4	86.8	985	80	“
0600	30.1	85.7	987	70	“
1200	31.3	84.0	990	45	tropical storm
1800	32.4	82.4	994	40	extratropical
04/0000	33.2	80.5	994	40	“
0600	34.5	79.0	995	50	“
1200	35.9	77.2	998	50	“
1800	36.5	75.0	1000	50	“
05/0000	38.0	71.0	1000	50	“
0600	40.0	65.5	998	50	“
1200	42.5	61.0	990	50	“
1800	45.0	56.0	986	50	“
06/0000	47.0	54.0	979	50	“
0600	48.0	53.0	968	50	“
1200	49.0	52.0	964	55	“
1800	49.5	50.0	966	55	“
07/0000	50.0	48.0	968	55	“
0600	50.5	45.0	970	50	“
1200	51.0	41.0	978	45	“
1800	51.0	37.0	978	45	“
08/0000	51.0	32.0	982	40	“
0600	51.5	28.5	982	40	“
1200	52.0	25.0	983	35	“
1800					absorbed by a larger extratropical low
03/0000	29.4	86.8	985	80	minimum pressure
03/0600	30.1	85.7	987	70	landfall near Panama City, Florida

Table 2. Hurricane Earl selected surface observations, September 1998.

Location	Press. (mb)	Date/ time (UTC)	Sustained wind (kts) <sup>a</sup>	Peak gust (kts)	Date/ time (UTC) <sup>b</sup>	Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	total rain (in)
<b>Louisiana</b>								
New Orleans	1003.7	02/2251	25	31	02/1658			0.24
International Arpt								
New Orleans	1003.4	02/2258	29	32	02/1658			0.31
Lakefront Arpt								
Venice	1000.3	02/1504	29	38	02/1820			
Slidell			21	27	02/2112			2.51
California Bay						5.3		
Lake Pontchartrain						3.7		
Industrial Canal								
Lake Borgne						4.9		
Bayou Bienvenue								
<b>Mississippi</b>								
Pascagoula Trent Lott Arpt	1002.4	02/2232	21	29	02/2014			1.08
Gulfport			23	29	02/1846			
Bay St Louis								4.24
<b>Alabama</b>								
Mobile Regional Arpt	1002.7	03/0011	23	28	02/1913			2.45
Mobile Brookley Field	1002.4	03/0028	24	31	02/2120			1.32
Evergreen	1002.0	03/0755	18	24	03/0223			0.07
Mobile State Docks							1.9	
Little Dauphin Island Bay							2.6	
Bayou La Batre							2.7	
Fairhope Agricultural Station				26	02/2200			2.17
Grand Bay Agricultural Stn				32	03/2033			2.24
Seemes Agricultural Station				16	01/1913			1.69
Tillmans Corner								6.90
Dothan Airport	994.2	03/0919	22	31	03/0528			5.36
<b>Florida</b>								
Pensacola Regional Arpt	998.3	03/0100	32	49	03/0047			3.06
Pensacola Naval Air Station	997.6	02/2356	32	43	02/1800			2.81
Crestview	995.6	03/0601	35	47	03/0424			6.03
Destin	994.2	03/0610	30	41	03/0222			2.50
Hurlburt Field AFB	994.9	03/0527	31	44	03/0426			5.45
Eglin AFB	997.6	03/0655		38	03/0354			6.31
Whiting Field (Milton)	1000.0	03/0600	23	37	03/0300			2.22
Panama City-Bay City	987.1	03/0725	36	46	03/0612			12.46
International Airport								
Panama City (5 mi northeast)								16.38
Marianna Municipal Airport	990.5	03/1004	32	42	03/1002			5.96
Tallahassee Regional Airport	989.5	03/1005	29	40	03/0959			5.41
Perry-Foley Airport	996.6	03/1026	24	32	03/0432			4.40
Cross City Airport	999.0	03/0700	19	26	02/2232			4.27
Apalachicola	990.5	03/0833						
Shell Point				51	03/0310			
FSU Dept. of Meteorology				42	03/1020			5.25

Table 2 (continued). Hurricane Earl selected surface observations, September 1998.

Location	Press. (mb)	Date/ time (UTC)	Sustained wind (kts) <sup>a</sup>	Peak gust (kts)	Date/ time (UTC) <sup>b</sup>	Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	total rain (in)
<b>Florida</b>								
Turkey Point DARDC			38	57	03/1000			
Brooksville (BKV)	1003.7	03/0306	32	41	03/1136			3.00
New Port Richey (RRF)	1004.4	03/0246	29	40	03/1103			3.07
Clearwater Tide Gauge			26		03/0750			
St Petersburg/Clearwater (PIE)	1005.1	03/0731	22	39	03/1550			1.62
St Petersburg (PIE)	1004.1	03/0248	33	39	03/0323			
Uncommissioned ASOS								
St Petersburg (SPG)			34	41	03/0322			
St Petersburg Pier			21	33	03/0700			
Tampa Airport (TPA)	1004.1	03/0252	32	39	03/1108			0.87
MacDill AFB (MCF)	1008.5	03/0239	24	34	03/1330			1.41
Old Port Tampa			23	38	03/1330			
Sunshine Skyway			33	42	03/1730			
Winter Haven (GIF)	1006.4	03/0519	28	34	03/1303			0.46
Lakeland (LAL)	1006.9	03/1050	10	28	03/0500			
Sarasota/Bradenton Arpt (SRQ)	1004.4	03/0252	32	41	03/1205			
Lido Key Tide Gauge			26		03/0750			
Punta Gorda (PGD)	1007.5	03/0509	23	29	03/1316			0.06
Fort Myers (FMY)	1007.5	03/0507	23	29	03/1246			0.40
Regional Southwest Arpt (RSW)	1007.1	03/0455	23	29	03/1238			0.02
Inverness								1.40
Ruskin (TBW)								0.73
Escambia County						2-3 <sup>e</sup>		
Santa Rosa County						3 <sup>e</sup>		
Okaloosa County						4 <sup>e</sup>		
Franklin County						8 <sup>e</sup>		
Wakulla County						8 <sup>e</sup>		
Jefferson County						8 <sup>e</sup>		
Taylor County						8 <sup>e</sup>		
Dixie County						6-7 <sup>e</sup>		
Levy County							5-7 <sup>e</sup>	
Citrus County							4-5 <sup>e</sup>	
Hernando County							3-4.5 <sup>e</sup>	
Pasco County							3-4.5 <sup>e</sup>	
Pinellas County							3-4.5 <sup>e</sup>	
Hillsborough County							3-4.5 <sup>e</sup>	
Manatee County							3-4.5 <sup>e</sup>	
Sarasota County							2-3 <sup>e</sup>	
Charlotte County							2-3 <sup>e</sup>	
Lee County							2-3 <sup>e</sup>	

Table 2 (continued). Hurricane Earl selected surface observations, September 1998.

Location	Press. (mb)	Date/ time (UTC)	Sustained wind (kts) <sup>a</sup>	Peak gust (kts)	Date/ time (UTC) <sup>b</sup>	Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	total rain (in)
<b>CMAN Stations</b>								
Grand Isle (GDIL1)	1002.4	02/1600	31	40	02/1100	4.1		
Dauphin Island (DPIA1)	1001.1	02/2200	38	47	02/1900			
Cape San Blas (CSBF1)	991.0	03/0500	48 <sup>f</sup>	61	03/0500			
Cedar Key (CDRF1)	1001.9	03/0700	37	47	03/0900			
Venice (VENF1)	1007.0	03/0800	30	36	03/0500			
Keaton Beach (KTNF1)	998.3	03/1100	41 <sup>f</sup>	55	03/0950			
Southwest Pass (BURL1)	999.0	02/1500	37 <sup>f</sup>	48	02/1410			
<b>NOAA Buoys</b>								
42040	994.9	02/1900	41	55	02/1500			
42039	989.4	03/0100	45	63	03/0100			
42036	999.9	03/0300	35	47	03/0300			
42002	1000.6	01/2300	26	34	31/2000			
42001	998.9	02/1000	37 <sup>f</sup>	52	01/1000			
42007	1000.5	02/2200	30	37	02/1700			
42003	1002.2	03/0100	35 <sup>f</sup>	45	02/1700			

<sup>a</sup>Standard NWS ASOS and C-MAN averaging period is 2 min unless otherwise indicated; buoys are 8 min unless otherwise indicated.

<sup>b</sup>Date/time is for sustained wind when both sustained and gust are listed.

<sup>c</sup>Storm surge is water height above normal astronomical tide level.

<sup>d</sup>Storm tide is water height above NGVD.

<sup>e</sup>Estimated.

<sup>f</sup>10 min averaged wind.

Table 3. Watch and warning summary, Hurricane Earl, September 1998.

Date/time (UTC)	Action	Location
01/2100	hurricane warning	Pascagoula, MS to Cameron, LA
01/2100	hurricane watch	east of Pascagoula, MS to Destin, FL
01/2100	hurricane watch	west of Cameron, LA to High Island, TX
02/0300	tropical storm warning	east of Pascagoula, MS to Destin, FL
02/0900	hurricane watch and warning discontinued	west of Morgan City, LA
02/0900	hurricane warning extended eastward	Pascagoula, MS to Destin, FL
02/0900	tropical storm warning	east of Destin, FL to Apalachicola, FL
02/0900	tropical storm watch	west of Morgan City, LA to Cameron, LA
02/1300	hurricane warning extended eastward	Destin, FL to mouth of the Suwannee River, FL
02/1300	watches and warning discontinued	west of Pascagoula, MS
02/1300	tropical storm warning	south of the mouth of the Suwannee River, FL to the Anclote Keys, FL
02/1700	hurricane watch and tropical storm warning	west of Pascagoula, MS to Grand Isle, LA including New Orleans
03/0300	watches and warnings discontinued	west of the AL/FL state line
03/0900	hurricane warning discontinued	Panama City, FL westward
03/1500	hurricane and tropical storm warnings discontinued	remainder of Gulf coast

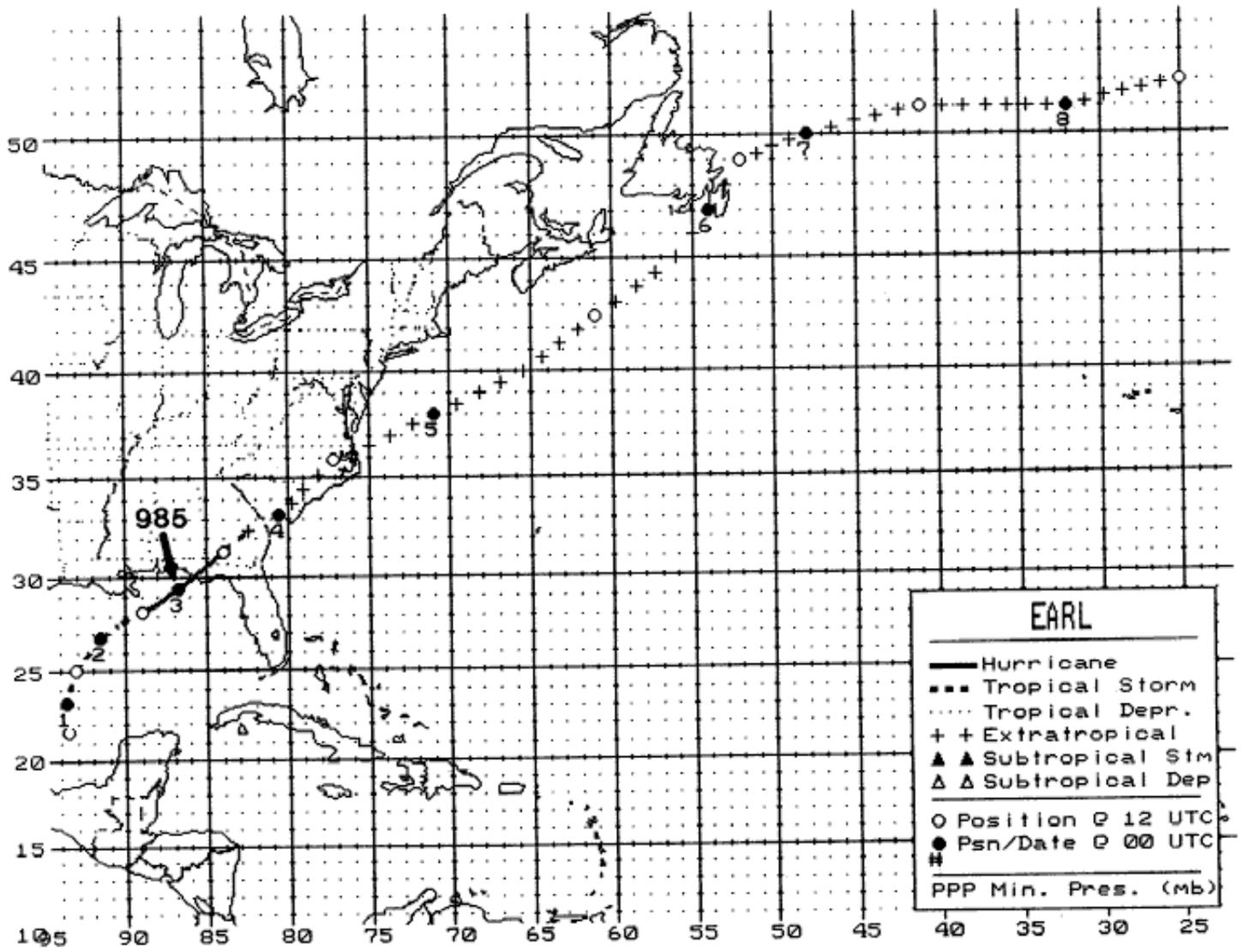


Figure 1. Best track positions for Hurricane Earl, 31 August - 3 September 1998.

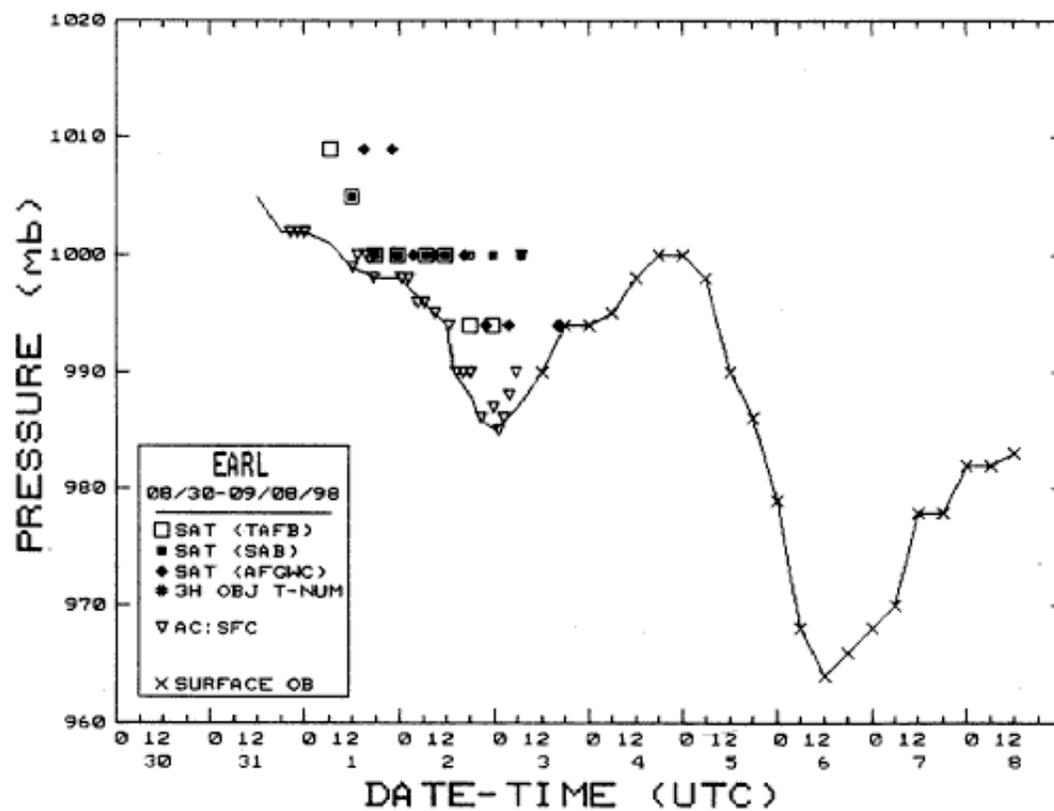


Figure 2. Best track minimum central pressure curve for Hurricane Earl.

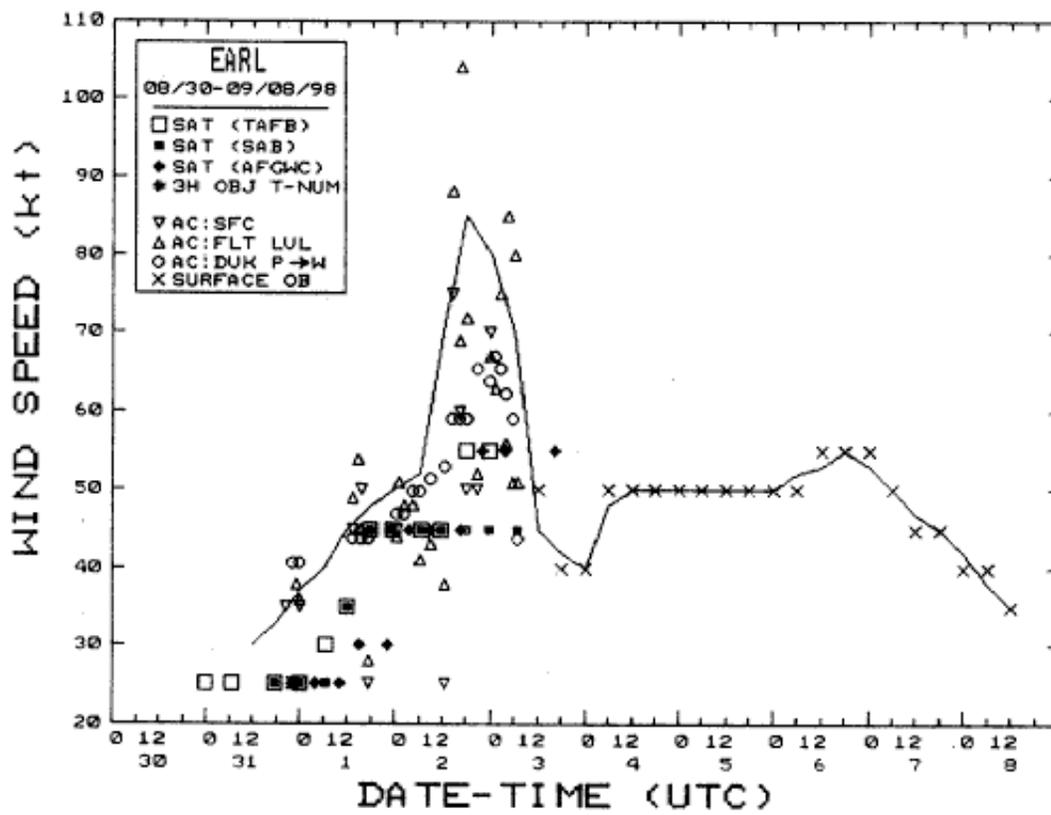


Figure 3. Best track maximum sustained wind speed curve for Hurricane Earl.